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Potential and challenges of blockchain technology implementation in Higher Education: A systematic literature review

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ABSTRACT

This study examined the potential applications and challenges of implementing blockchain technology within higher education systems. Blockchain, known for its decentralized and immutable nature, attracted significant interest due to its ability to provide secure, transparent, and efficient data management. In the context of higher education, blockchain has the potential to revolutionize academic record management, enhance verification processes, prevent fraud, and ensure the authenticity of credentials. This systematic literature review identified key use cases, such as academic credentialing, student data management, and the protection of intellectual property in research. Despite its promising potential, the adoption of blockchain in higher education, particularly in Indonesia, remained in its early stages. The study discussed major obstacles to implementation, including technical limitations, high costs, limited awareness, and regulatory barriers. Addressing these challenges required further research and collaboration between academic institutions, government agencies, and technology providers to enable widespread adoption. The review emphasized the need for a comprehensive framework to guide the practical implementation of blockchain, ensuring its benefits could be fully realized in educational environments.

Keywords: Blockchain, Higher Education, Technology

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INTRODUCTION

The development of information and telecommunications technology is an important factor for the survival of humanity. The use of Information Technology is no longer just a tool but a mandatory component that must be possessed. The rapid advancement of Information Technology, which greatly facilitates human activities, has led to a high level of dependence on its presence. Over the past few decades, this has driven new innovations in various fields.

The Fourth Industrial Revolution (Industry 4.0) represents a massive transformation in the industrial world due to the emergence of technological advancements in resource management, making every process far more effective and efficient than before. Industry 4.0 has driven society to create more disruptive technological innovations or shift activities from the physical world to the virtual one. In general, Industry 4.0 describes a

growing trend toward automation and information exchange within technology and processes in the manufacturing industry. This trend includes the Internet of Things (IoT), the Industrial Internet of Things (IIoT), Cyber-Physical Systems (CPS), Artificial Intelligence (AI), Smart Factories, and Cloud Computing systems that encompass every process from production to distribution, all of which are experiencing a revolution in terms of sustainability.

One of the technological developments of the digital-based Fourth Industrial Revolution is blockchain technology. Blockchain technology was introduced in 2008 by Satoshi Nakamoto and was initially used as a peer-to-peer ledger in Bitcoin cryptocurrency transactions (Nakamoto, 2008). Blockchain is one of the technological inventions that operates on the concept that transactions can be reliably recorded without the need for third-party guarantees, allowing users to collectively verify transaction-related information (Bahga & Madisetti, 2016). Simply put, blockchain is a global online database that can be used by anyone worldwide who is connected to the internet.

The main feature of blockchain technology is that no single institution guarantees the validity of a transaction's status; instead, all users act as guarantors (decentralization), minimizing the risk of system disruptions or failures. The advantages of blockchain technology, such as immutability, transparency, and trust, are known to work not only in cryptocurrencies but also in other industries, particularly in education. Blockchain technology, which has often been a topic of public discussion, has the potential to revolutionize learning processes in the era of the Fourth Industrial Revolution. The combination of knowledge between the fields of education and blockchain technology will bring about a new revolution in the education industry, in line with current technological advancements.

The rapid development of information and telecommunications technology has transformed various sectors, including education. The Fourth Industrial Revolution, characterized by technological innovations like the Internet of Things (IoT) and Artificial Intelligence (AI), has prompted a shift from traditional methods to automated systems. Blockchain technology, originally introduced in 2008 for cryptocurrency transactions, has emerged as a promising tool beyond financial services, with potential applications in education.

Despite the progress made in education, issues such as the manipulation of academic records and verification processes persist. Blockchain's decentralized, tamper-proof data storage could address these challenges by enhancing transparency and trust in educational institutions. This study aims to explore the potential applications and challenges of implementing blockchain technology in higher education, with a focus on its relevance to Indonesia's educational landscape.

The education system, amidst the rapid development of technology, is expected to begin transforming into a technology-based education system. The goal of its implementation is to foster curiosity, which will encourage students to continue learning and developing their knowledge and skills. Education with an information technology system is expected to help develop facilities and shift mindsets aimed at meeting the evolving needs of students and other academic communities in building a connected learning environment. Blockchain technology has become a trend and a hot topic of discussion in society due to its potential in the education industry, particularly in higher education institutions.

As centers for the development of science and technology, universities are expected to enhance their role in supporting national development (Sukirman & Sari, 2012) and produce graduates who are capable of advancing knowledge and technology, as well as creating innovations (Dirwan, 2020). However, in reality, numerous problems still exist within the education system, ranging from verification processes that can be manipulated to the involvement of third parties in various systems within the educational ecosystem. Examples include bribery to gain admission to schools or universities, bribing and manipulating grades to get into prestigious universities, and even some universities engaging in diploma forgery. Such dishonesty degrades the quality of human resources and casts doubt on the quality of education in Indonesia. With the advent of blockchain technology, these issues within the education industry have the potential to be addressed by implementing this technology.

Blockchain can function as a data storage medium in the world of education, such as recording grades, managing student information, and storing educational materials. It can also make it easier for users to access files from other computers without relying on just one. In the context of education, blockchain can be likened to a "CCTV"—this digital footprint can enhance the integrity of education in Indonesia by fostering students' honesty, education, and good ethics.

The use of blockchain technology in the education sector is still in its early stages. However, several educational institutions are beginning to apply blockchain technology for verification purposes and to share academic certificates or student assessment results (Perkasa, 2020). Other researchers believe that blockchain technology offers many more benefits for educational institutions. Research shows that the increased integration of blockchain technology is an effective trend to apply in the education sector because blockchain's information storage uses a distributed database that minimizes data destruction and reduces the level of fraud (Aini et al., 2021). The implementation of blockchain technology can weaken the central role of educational institutions as certification agents while providing greater learning flexibility for students (Nespor, 2018). Blockchain can also offer benefits such as secure and transparent data sharing, avoiding the forgery of academic documents, and

providing a cooperative and reliable work environment (Ramos & Queiroz, 2022).

The potential benefits of blockchain technology are still not well understood by the public, especially in Indonesia, leading to obstacles in its application across various fields. The potential of blockchain technology still needs to be researched more intensively, particularly regarding its utilization in higher education. In addition to the potential benefits of blockchain technology that remain largely unrecognized, further research and development are needed. Therefore, more in-depth studies should be conducted on the potential and challenges of implementing blockchain technology in higher education.

LITERATURE REVIEWS

Disruptive Innovation

Disruptive Innovation, in Indonesian, means innovation that disrupts or disturbs. Disruption, in line with technological advancements in this context, refers to the emergence of new technological innovations that disturb the existence of older technologies.

Clayton M. Christensen popularized the term disruptive innovation in 1997. Disruptive innovation was first introduced with the term disruptive technology. Christensen introduced the concept of disruptive innovation as a form of disturbance caused by newcomers.

Disruption is an innovation that will replace the entire old system with a new one (Kasali, 2008). Disruption has the potential to replace outdated technologies that still use manual systems with digital technologies that produce something entirely new, efficient, and more beneficial. This era of disruption is a phenomenon in which society shifts actions previously carried out in the physical world to the virtual one.

The theory of disruptive innovation explains the phenomenon where an innovation changes the existing market or industry by introducing simplicity, convenience, accessibility, and affordability (Lasmawan, 2019). Disruptive innovations are not technological breakthroughs that make products better but rather discoveries that make products and services easier to access and affordable, thereby making them available to a much larger population.

The Fourth Industrial Revolution

The development and enhancement of technology occurred during the era of the Fourth Industrial Revolution, which was initiated at the World Economic Forum (WEF) in 2015 by German Chancellor Angela Merkel along with Klaus Schwab, the founder of the forum. Professor Klaus Schwab, a renowned German economist, presented the concept of the Fourth Industrial Revolution in his book titled “The Fourth Industrial Revolution.” In this book, Prof. Schwab explains that the Fourth Industrial Revolution has fundamentally changed the way people live and work (Schwab, 2016). Although it remains a topic of debate, Klaus Schwab believes that we have now entered the era of Industry 4.0, more commonly known as the cyber-physical system industry.

The Fourth Industrial Revolution is the name of the latest trend in automation and information exchange within manufacturing technology (Darma et al., 2020). This term encompasses cyber-physical systems, the Internet of Things, cloud computing, and cognitive computing. Some important issues in this Fourth Industrial Revolution include how governments, large and small industry players, academics, and the general public respond to the potential advances in information technology that affect various business models. All of these factors influence changes in the industry itself, striving to control production processes. These changes can reach the entire value chain, benefiting both rural and urban populations (Rosyadi, 2018).

The Fourth Industrial Revolution can be described as the fourth stage in the historical journey of industrial revolutions that began emerging in the 18th century. According to Professor Schwab (2017), the world has experienced four periods of industrial revolution (Schwab & Howell, 2015). It began with the first industrial revolution, marked by the invention of the steam engine, which powered production machines, trains, and sailing ships. This was followed by the discovery of electrical energy and the concept of division of labor for mass production, which emerged in the early 19th century, marking the birth of the second industrial revolution. The rapid development of science and technology in the early 20th century led to the emergence of information technology and automated production processes, signaling the third revolution, which relied more on machine power in industries than on human labor.

The current industrial revolution is reaching its peak, characterized by the advent of digital technology, which has a significant impact on the lives of people worldwide. The fourth generation of industrial revolution emphasizes automation systems in all activity processes. By 2022, the number of internet users in Indonesia reached 210 million, equivalent to 77.2 percent of the total Indonesian population (Asosiasi Penyelenggara Jasa Internet Indonesia, 2022; Pidada, 2023). The Fourth Industrial Revolution fosters the creation of more technological innovations that lead to disruptions in societal life or shift activities from the physical world to the virtual one (the Internet).

Blockchain Technology

The word 'technology' originates from the Greek words *techne*, meaning 'skill,' and *logia*, meaning 'knowledge.' In a more specific sense, technology refers to objects that facilitate human activities, such as machines, tools, or hardware. According to the Merriam-Webster dictionary, technology is defined as the ability acquired through the application of knowledge and practice to specific tasks. Based on these definitions, it can be concluded that technology is the science that studies the ability to create tools and processes that assist in fulfilling various human tasks and jobs.

Blockchain is one of the technological inventions that operates on the concept where transactions are recorded reliably without the need for guarantees from a third party, allowing each user to verify information related to transactions collectively (Bahga & Madisetti, 2016). In simple terms, blockchain is a decentralized online global database that can be used by anyone connected to the internet, without the need for trust among users. Digital assets (such as credit shares, bonds, stocks, or fundamental rights) are managed as an ordered list of transactions. Each block in the blockchain is linked to the previous block via a hash. Thus, the transaction history in the blockchain cannot be altered or deleted without changing the entire content of the blockchain.

The fundamental difference from current databases is the elimination of a central element, making data decentralized and distributed. This means there is no central control unit that verifies the truth of the data. Therefore, blockchain uses a consensus mechanism. This allows data sent to be integrated into the blockchain only after approval (consensus). If the relevant requirements are met, transactions confirmed by consensus can be tracked and secured against manipulation or forgery by third parties.

METHODS

This research employs a qualitative methodology, utilizing a systematic literature review approach. Systematic literature reviews serve as a means to identify, evaluate, and interpret all existing research relevant to the research questions, topics, or phenomena under investigation. According to Cooper (1907), the purpose of using systematic literature reviews is to critically analyze various relevant sources and identify central issues in the field (Lame, 2019). These issues may include questions about the topic being researched.

Following Kitchenham's (2004) guidelines for systematic review procedures, this study identified relevant academic articles from 2016 to 2022 (Kitchenham, 2004). Articles were sourced from reputable databases including Google Scholar, ResearchGate, Elsevier, and Emerald Insight using keywords such as "Blockchain," "Blockchain Implementation," and "Blockchain in Higher Education."

A total of 52 articles were initially selected. After screening for relevance, duplication, and alignment with the research objectives, 31 articles were included in the final analysis. These articles were thoroughly reviewed to identify central themes related to blockchain's potential and challenges in the education sector.

The data for this study comes from secondary sources, including the collection and analysis of relevant articles and journals published in reputable academic outlets. The research employs internet-based journal searches using software such as Publish or Perish (PoP), Google Scholar, ResearchGate, Elsevier, and Emerald Insight. Keywords used in these searches include 'Blockchain,' 'Blockchain Implementation,' 'Blockchain Opportunities and Challenges,' 'Blockchain Implementation in Education,' and 'Blockchain Implementation in Higher Education Institutions.'

The results from searches conducted using Publish or Perish (PoP), Google Scholar, ResearchGate, Elsevier, and Emerald Insight are filtered based on titles relevant to this research. Subsequently, the selected journals are read thoroughly to identify similarities within the studies. At this stage, if any irrelevant journals are found, they will be removed from the research references. Journals that specifically discuss the application of blockchain in education and higher education will be included. The final selected data will then be entered into a thematic map along with the main themes and sub-themes related to the potential and challenges of blockchain technology in higher education, from which conclusions will be drawn in the study.

RESULTS AND DISCUSSION

Results

The article search was conducted in October 2022. The initial search focused on publications from 2016 to 2022, using keywords such as 'Blockchain,' 'Blockchain Implementation,' 'Blockchain Opportunities and Challenges,' 'Blockchain Implementation in Education,' and 'Blockchain Implementation in Higher Education Institutions.' The search results, conducted through the Publish or Perish (PoP) application, yielded 24 articles from Google Scholar, 20 articles from ResearchGate, 2 articles from Emerald Insight, and 6 articles from Elsevier, for a total of 52 articles.

The obtained articles were subsequently re-selected based on their titles, abstracts, duplicates, and overall text, leading to the identification of primary studies that would be used for further analysis. Among these, 9 articles were found to be inconsistent with the research topic or theme. Additionally, 2 similar articles had to be

excluded, resulting in 41 articles being read thoroughly to assess their relevance to the research topic or theme. Ultimately, 31 articles were selected for further analysis.

The figure below shows the number of selected articles published from 2016 to 2022, with 1 article in 2016, followed by 5 articles in 2017. In 2018, there were only 2 articles relevant to the research. In 2019, the highest number of articles was obtained, totaling 8 articles, followed by 5 articles in 2020, 7 articles in 2021, and 3 articles in 2022.

This study is aimed at investigating the role of marketing strategies including digital marketing, social media marketing, content marketing, and online advertising in influencing brand creation in SMEs in Malaysia. This study involved 51 MSME business actors, that can be seen the majority of respondents were MSME actors aged 20-30 years (33.3%), female (51%), and acted as social media marketers (33.3%), marketing specialists (33.3%), and influencer marketer (33.3%).

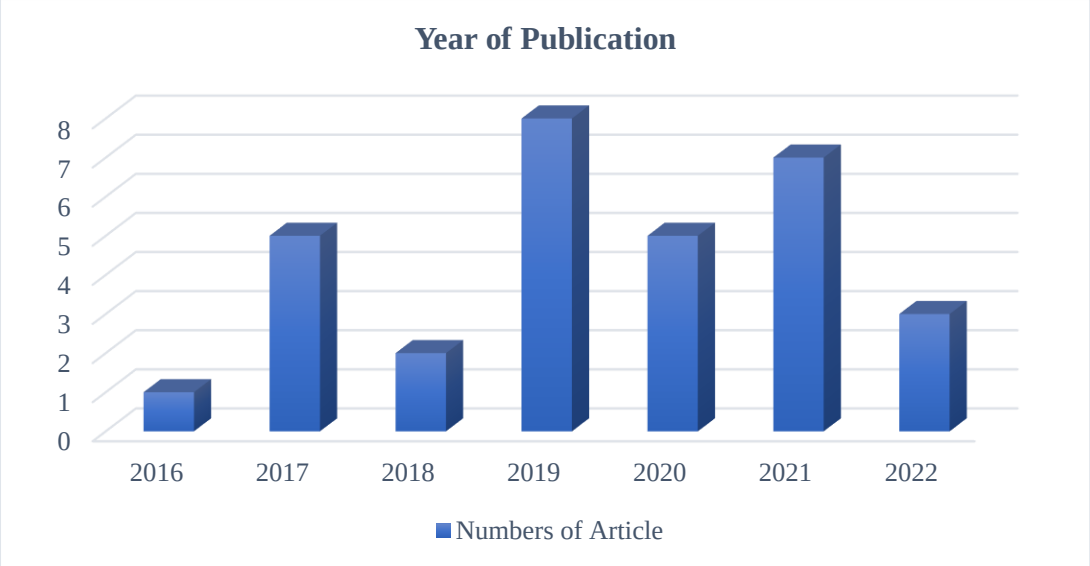

FIGURE 1. The Distribution of Articles Across The Years

After thoroughly reading all the selected articles, three main themes were identified as key factors in the implementation of blockchain technology in higher education: the implementation of blockchain technology in the education sector, the potential of blockchain technology in higher education, and the challenges of implementing blockchain technology in higher education. Figure 2 illustrates the thematic map of the discussion.

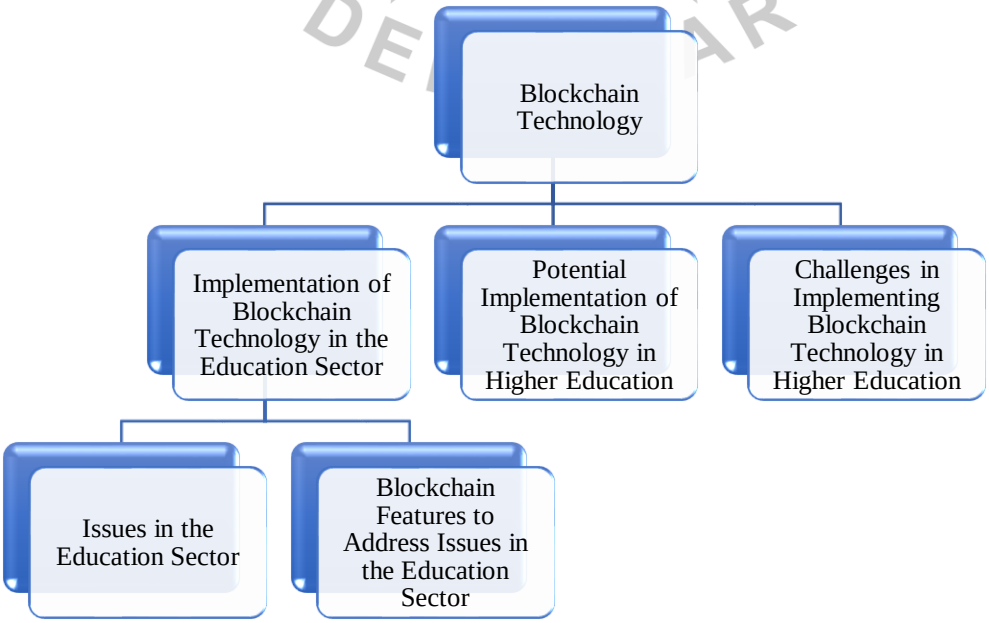

FIGURE 2. The Thematic Map of The Discussion

Discussion

Implementation of Blockchain Technology in Higher Education

Education is an essential element that cannot be neglected, as it plays a crucial role in the advancement of a nation. However, educational institutions still face various challenges in terms of physical infrastructure, digital systems, and financial management. These ongoing issues hinder the efficiency and quality of education.

As a result, innovative technologies like blockchain have become a prominent topic of discussion as a means to support the education sector. Blockchain technology offers a decentralized solution to several issues in the education sector, such as the verification of academic records, grade management, and the reduction of fraudulent activities. Its ability to create immutable records and secure data sharing can improve the overall efficiency and integrity of educational institutions. For example, several universities worldwide have started using blockchain for sharing student credentials and academic certificates.

This section will delve into the specific problems faced by educational institutions and explore how blockchain technology can address these issues.

Issues in the Education Sector

The education sector encounters several significant challenges, particularly in the physical, digital, and financial aspects of its operations.

The physical aspect encompasses various activities related to manual processes and the handling of physical education records. One major issue is the risk of manipulation. The involvement of humans in creating physical records, such as administering and grading paper-based exams, increases the likelihood of unauthorized individuals altering academic records. Such manipulation can lead to favoritism, as unauthorized parties may change a student's grades. Existing mechanisms for securing academic records, such as degrees and transcripts, can be easily reproduced and are often indistinguishable from original documents, making them vulnerable to manipulation (Yumna et al., 2019).

Verification of academic records is another challenge. Many countries lack centralized records from all universities, complicating the verification process (Gräther et al., 2018). This situation makes it challenging to verify documents from institutions where archives and records are still maintained manually. Furthermore, traditional education systems often require significant human resources for both students and institutions. For instance, if a student loses their academic certificate, they must navigate a lengthy and costly process to have it reissued. Institutions must also verify records through multiple steps, such as checking and matching previous student records, while maintaining physical records for extended periods (Grech & Camilleri, 2017).

A critical issue in this context is the concept of a single point of failure. Educational institutions centralize student records under one entity, which creates vulnerabilities. Even if some distributed technologies are employed, these records can still be shared by untrustworthy parties. Conventional educational records, stored physically in specific locations, pose a significant risk. If these physical records are lost or damaged due to unforeseen circumstances, such as fire, recovering the documents becomes nearly impossible (Grech & Camilleri, 2017).

Digital aspects refer to any records or activities stored or conducted electronically or online. One primary concern is the need for third-party approval. Academic assessments are made by educators, but the recorded evidence—whether digital or physical—is often generated by third parties (Grech & Camilleri, 2017). This reliance opens the door for the production of fraudulent academic records by these third parties (Hoy, 2017).

Security is another critical issue. Similar to vulnerabilities in physical records, digital records are often accessed from centralized sources, leading to the potential for unauthorized data alterations, whether intentional, accidental, or illegal. If these sources are compromised, all digital data could be manipulated or lost (Grech & Camilleri, 2017). Furthermore, the exchange of records between institutions can be extremely complicated and time-consuming, often making it impossible. For instance, if a student wishes to transfer from one university to another, exchanging records becomes a challenging process. Students also encounter difficulties when applying for admission, as they are required to submit all their educational records (Turkanović et al., 2018).

The financial aspect pertains to the study and management of money, with highlighted issues related to funds and budgeting. One significant concern is the presence of intermediary commissions. Universities conduct thousands of transactions monthly with students, staff, vendors, suppliers, and government agencies. This creates opportunities for corruption by higher authorities. Implementing decentralized audits within the financial systems of institutions could help mitigate these risks (Yumna et al., 2019).

Lastly, the lack of a clear structure for monitoring and evaluating the performance of students and faculty in educational institutions can lead to a loss of motivation. Without recognition for their hard work, individuals may feel undervalued. It is essential to provide rewards for good performance and maintain records to encourage and motivate both students and teachers (Chen et al., 2018; Rooksby & Dimitrov, 2019).

Addressing these multifaceted challenges requires innovative solutions, particularly through advancements in technology like blockchain, which can enhance security, efficiency, and transparency in educational institutions.

Blockchain Features to Address Issues in the Education Sector

Blockchain technology offers several features that can effectively address the challenges faced in educational institutions. One key attribute is decentralization, which maintains excessive records across a distributed network. This decentralization helps to reduce risks associated with manipulation, as it makes it difficult for attackers to alter records managed by multiple nodes, compared to a centralized system where a single node holds all the records(Yumna et al., 2019). It also simplifies verification processes by providing an open-source, distributed platform that contains numerous copies of transactions shared across all nodes in the network (Turkanović et al., 2018). Furthermore, it lessens the demand for human resources by alleviating administrative burdens in various scenarios, such as verification or migration, thereby minimizing the costs and efforts associated with traditional manual labor. For instance, if a student transfers from one university to another, the faculty of the new institution can easily verify the student's records from the blockchain database(Turkanović et al., 2018). Additionally, decentralization helps to eliminate single points of failure by storing copies of data on every node, ensuring that if one node goes offline, the data remains safe within the redundant network (Grech & Camilleri, 2017). It also facilitates information exchange between institutions, making it easier and more convenient to share records, particularly for transfers and further studies (Turkanović et al., 2018).

Another important feature of blockchain is traceability, which refers to the ability to track and trace everything back to its origin. This characteristic can reduce risks of manipulation; if someone attempts to execute an illegal transaction or make changes within the blockchain, it can be traced back through the linked blocks using the hash keys from the blockchain's chronicle. Thus, any modifications or fraudulent activities can be detected (Yumna et al., 2019). Traceability also enhances security by establishing a proof of existence and ownership, as blockchain technology creates digital signatures for each transaction that are nearly impossible to replicate compared to electronic signatures (Yumna et al., 2019).

Smart contracts, another vital feature, are computer programs that facilitate, verify, or enforce negotiations or the performance of a contract digitally without the need for a third party, often distributed across the blockchain nodes. Smart contracts can help address issues of performance proof by enabling real-time payments based on the terms set within the contract, allowing for instant rewards to be given to students and teachers based on their performance (Chen et al., 2018). They also reduce the demand for human resources by automating manual operations within smart contracts, thus streamlining processes that typically require human intervention. Additionally, smart contracts can automate intermediary operations, such as verifying degrees across different blockchain platforms, all while maintaining minimal fees for contract execution and ensuring transparency throughout the process.

Consensus mechanisms refer to the collective agreement among all nodes within a blockchain network. These mechanisms help resolve various issues, including manipulation risks, as data is aggregated in the blockchain through different consensus mechanisms and is not controlled by a single entity. This significantly reduces the chances of fraud and errors, since each transaction is verified by other nodes in the network. Moreover, consensus mechanisms eliminate the need for third-party approval, as blockchain frameworks operate independently of intermediaries, allowing governance protocols to function as smart contracts.

Lastly, cryptocurrency, a form of digital or virtual currency that uses strong cryptographic techniques and is generated through various mining algorithms, can also address several challenges. For instance, by introducing educational currencies, rewards or appreciation for performance can be granted in the form of cryptocurrency through smart contracts to students and teachers who excel. This type of currency can be stored in educational wallets and exchanged for other currencies(Rooksby & Dimitrov, 2019).

Overall, these blockchain features collectively provide innovative solutions to the challenges faced in educational institutions, fostering a more secure, efficient, and transparent educational landscape.

Potential Implementation of Blockchain Technology in Higher Education

In the midst of rapid advancements in science and technology, the education sector, which is one of the most important factors in Indonesia's progress, has yet to implement blockchain technology in its learning and management systems. Education utilizing blockchain technology is expected to help meet the evolving needs of students and the broader academic community in creating an interconnected learning environment. Blockchain technology has now become a trend and a hot topic in society due to its potential in the higher education industry. Some of the potential applications of blockchain technology in higher education are as described in the following paragraphs.

The first is building trust among parties. Due to its advanced features, blockchain technology can develop relationships among several smart devices. Only verified devices can interact within the system; this also applies to the institutions involved in the system. Before joining, each block of transactions will be confirmed, and only after confirmation can they be added to the blockchain(Turkanović et al., 2018).

The second is efficiency in time. Blockchain minimizes transaction times from what would typically require weeks to just a second. For instance, in traditional approaches, when a student wants to enrol in a university, they spend a lot of time filling out forms and waiting for responses from the university

administration. With blockchain, this process can be automated, thus saving time and effort.

The third is educational security management. Blockchain offers security for users, devices, and data by allowing peer-to-peer data transfer. This is achieved by distributing the database across multiple points, eliminating reliance on a single server. The use of blockchain also plays a crucial role in checking or reducing the potential for resource failures or transaction errors (human error). Future smart campuses should utilize blockchain systems to ensure transparency and security (Fernández-Caramés & Fraga-Lamas, 2019). In this regard, blockchain, particularly smart contracts, can provide a new level of security, trust, and transparency for e-learning activities and collaborative learning environments, ensuring the validity of exam assessments, credential issues, and information storage in e-portfolios, as well as offering significant improvements in security and efficiency for educational institutions and learners.

The fourth is the activities of educational institutions. Blockchain can also transform certain roles within educational institutions. It will serve as an excellent format for providing qualifications and experiences, removing the role of institutional administrators as delivery points (Alam & Benaida, 2020). This will also reduce the profit flow to institutions, cut costs, or enable services to be distributed anywhere. Currently, higher education institutions worldwide have introduced their personnel to blockchain courses, recognizing the value of advancements in blockchain technology. Utilizing blockchain also facilitates institutions to exchange information openly through an open source blockchain easily and conveniently, such as in cases of transfers and for further study purposes (Turkanović et al., 2018). Authenticated users can connect and exchange information, thus easing students and institutions in seeking student information.

The fifth is the accreditation of studies/educational institutions. Accreditation is crucial for higher education institutions. To achieve this, regarding study accreditation, recognition, and credit transactions, several universities, large companies, and start-ups propose systems that can streamline the process and ensure the authenticity of students' achievements. Among the most promising initiatives is the creation of the global higher education credit platform, EduCTX. This platform is based on the European Credit Transfer and Accumulation System (ECTS) concept and aims to provide reliable digital solutions for credit systems and higher education assessments by reducing documentation, enhancing communication among institutions, and simplifying the management and storage of certificates for students (Turkanović et al., 2018). This platform is built on a globally distributed P2P network and uses the ECTX token as academic credits equivalent to the credit value of students for completed courses. Thus, it offers stakeholders (students, higher education institutions, private companies, organizations, or institutions) a global and decentralized education credit and assessment system (Turkanović et al., 2018).

Blockchain for verifying accreditation is also being considered in the work “Prospects for the Application of Blockchain Technology in Modern Education Systems” (Kirilova et al., 2018). Accredited organizations can create and publish "verifiers" on their websites, allowing any user to upload their diplomas and verify whether they were indeed issued by an accredited institution, as well as publish issued diplomas in a public register. This would allow any third party to verify the diplomas issued by a university for a student, whether the university is publicly accredited, and to ensure that the aforementioned information is indeed accurate.

The sixth is the management of competencies and learning outcomes. A good learning environment will provide meaningful support and feedback for students. This aims to enhance the learning process by implementing a broad range of skills, promoting critical thinking and problem-solving with better collaboration and communication. Experts introduced a decision-making system to assess students' knowledge and professional skills (Wu & Li, 2018). They developed it to establish an evaluation system that measures and organizes students' operational abilities. Lastly, some experts proposed the Student-Centered Learning Blockchain (SCi-B), a three-element system (E-Course, E-Portfolio, and E-Assessment) that can improve the learning process and enhance the credibility of student assessments (Purnama et al., 2021).

The seventh is as a distributed cloud storage: As decentralized cloud storage, blockchain can be used as an alternative medium for storing digital documents (Nugraha, 2022). Digital documents are often identified as individual pieces of paper in proprietary formats issued by vendors to their clients. Institutions without appropriate software may not be able to read or review them. Ultimately, both paper and digital documents can be forged by sophisticated users in ways that are hard to detect, necessitating the development of features in implementing blockchain technology as a distributed cloud storage medium.

The last is as a decentralized overseer. The role of an overseer in education is to verify and issue credential documents, such as certificates or transcripts digitally, with validation and verification processes that will reduce the occurrence of forgery or alteration of information content. In the implementation of blockchain technology, this scope is more commonly known as smart contracts (Nugraha, 2022).

Challenges in Implementing Blockchain Technology in Higher Education

Despite the vast potential of blockchain technology utilization in higher education institutions as previously explained, blockchain technology also faces challenges and obstacles in its implementation. Due to the limited research on the application of blockchain technology, further exploration and re-evaluation of how blockchain

can be implemented in other domains, particularly in higher education, are necessary. Here are some challenges in implementing blockchain technology in higher education that can also become obstacles for institutions related to this technology application.

The first is limited knowledge about blockchain technology. Blockchain technology is a new technological invention that has gained popularity in recent years with the emergence of the cryptocurrency Bitcoin. Although the principles of blockchain technology have existed since the 1980s, in reality, blockchain is a complex system to implement. Knowledge regarding the implementation and use cases is still very limited, leaving many parties uncertain and guessing how to technically implement blockchain technology across various fields, including higher education.

The second is the cost of implementing, maintaining, and developing blockchain technology. The implementation of any new technology always requires significant costs. In addition to the costs of acquiring the technology, there are also additional expenses. For instance, training costs for staff and educators to guide the operation of blockchain technology in higher education must be considered. Furthermore, it should be contemplated whether this technology will be implemented fully at once or in stages; the longer the implementation process takes, the higher the additional costs incurred.

The third is privacy and security issues are not fully resolved. Blockchain technology offers privacy guarantees because only public transaction data can be tracked while the personal identity of blockchain users remains protected/anonymized. However, on the other hand, many computer experts who have studied blockchain warn of issues related to personal data and security in this technology that are not yet completely perfect. One example of a data breach occurred on cryptocurrency platforms, with hacking or theft of crypto assets valued at around IDR 28.15 trillion in mid-2022. The surge in hacking incidents was attributed to the use of decentralized finance protocols, allowing cybercriminals to exploit vulnerabilities by studying the codes of ongoing transactions. Data within the blockchain is not directly encrypted. Blockchain is an open ledger system, that allows anyone to join and verify data transactions on the network, where the privacy of individuals involved is secured with cryptographic public keys. Therefore, educational institutions must enhance privacy and security by implementing private or permissioned blockchains (Oka & Syeira, 2022).

The fourth is an occurrence of errors in the system: Blockchain can experience errors or crashes due to high transaction loads. In 2019, cryptocurrency storage had more than 197 GB capacity. The heavy administrative load of transactions occurring simultaneously can cause system downtime.

The next is the storage capacity. All forms of records will be stored and archived indefinitely, which will increase storage size, creating a challenging task and a significant burden on other wireless devices.

Another challenge is confidentiality. Most records may be accessible and will be openly disseminated across any connected network. Any connected device can view blockchain transactions. Confidentiality will be difficult to maintain when using a public blockchain.

Legal and regulatory are also its challenges. Government regulations also pose a challenge in implementing blockchain technology as its application will alter the educational system's order. Since its concept eliminates intermediary parties in transactions and administration processes, the government needs to set boundaries and control interventions from this technology.

The last is about innovation challenges. In their study, Thayer (2018) claims that blockchain technology is not mature and is rapidly evolving, often causing blockchain projects to be vulnerable to failure, with over 90 percent never coming to fruition (Kaur, 2024). One implication of this is that the realization of these benefits and disruptions is likely to take longer than anticipated. Kandaswamy and Furlonger (2018) state that blockchain technology is intriguing but still relatively immature and carries a risk of failure (Price, 2019). Therefore, strong cooperation between governments, educational institutions, and innovators is essential in designing the implementation of blockchain technology in higher education institutions to ensure that innovations proceed as planned.

CONCLUSION

Blockchain technology is rapidly evolving and holds significant potential for transforming higher education by enhancing trust, security, and transparency in academic processes. Its applications include building stakeholder trust, increasing efficiency, and serving as a decentralized overseer. However, challenges such as limited knowledge, high implementation costs, unresolved privacy issues, and regulatory compliance hinder its adoption, particularly in Indonesia.

Currently, blockchain is not ready for immediate implementation in Indonesian educational institutions, as it remains in a developmental stage. There is a need for further research to clarify its potential and for real-world case studies from countries with successful blockchain implementations to guide future policy-making.

This study is limited to existing literature and lacks tangible examples of blockchain in education. Future research should involve in-depth investigations and case studies of institutions that have adopted blockchain technology to gather concrete insights.

The government should prioritize blockchain's potential by establishing a national research team focused on its development in higher education. Collaboration with countries that have successfully implemented blockchain technology will also be essential to adapt policies accordingly. Overall, effective integration of blockchain into Indonesian education will require cooperation among governments, educational institutions, and technology experts.

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